

# Current Status of NCSP Subtask 7 Subcritical Modeling

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# Statement of Work

- **1.1.1 Subcontractor shall assist Contractor in validating a developmental computational patch being added to the Los Alamos Monte Carlo N-Particle (MCNP) code's simulation capability for performing sub-critical neutron multiplication calculations through the following specific tasks :**
  - Acquire and compile codes
    - MCNP5 v. 1.51
    - MCNPX 2.6.0
    - MCNP-DSP
    - MCNP-PoliMi
    - PARTISN 5.97
  - Summarize relevant code capabilities
  - Perform simulations
  - Summarize simulation results and compare to MCNP5 multiplication (historic/ recent) results

# Task 1 Status: Partially Completed

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- All codes have been acquired
- MCNP5 v. 1.51, MCNPX 2.6.0, and MCNP-PoliMi have been successfully compiled
- MCNP-DSP has been compiled, however:
  - OS
  - Cross-section files
- PARTISN has been compiled
  - Cross-section sets have been compiled for use with code

## Task 2 Status: Completed

- **Relevant code capabilities beyond those of MCNP5 v. 1.51 have been summarized for:**
  - MCNP-PoliMi
  - MCNP-DSP
  - PARTISN
- **Limitations of MCNP5 v. 1.51:**
  - User can define location, direction, energy, time, and intensity of SF and ( $\alpha$ ,n) neutron sources
  - User **cannot** define fission events
    - e.g. sample number of neutrons emitted from  $\nu_{\text{bar}}$
  - User **cannot** define correlated (time, location) neutron sources
    - MCNP samples these values from user's input
  - User **cannot** (easily) record location and time of detection.
    - Possible using MCNP's PTRAC capability and a user-created external script to extract this information
  - MCNPX – some overlapping capability exists, but we are still investigating

# MCNP-PoliMi Overview

## ■ Modifications

- Analog particle tracking
- Correct neutron and gamma multiplicities have been included
- Correlation between neutron interaction and gamma production
- Conservation of energy for each interaction
- Secondary output file contains **list mode data**
  - Post-processing can be performed with included Matlab files to obtain detector response
    - Only for plastic scintillators
- Sources added
  - SF (Cf-252, U, Pu, Cm); Am-Be
  - Pu-Be and Am-Li to be added
- Can simulate up to 43 detector channels

## ■ Limitations

- No delayed neutrons
- No multigroup cross sections
- Limited to ENDF/B-VI and older

# MCNP-PoliMi Overview

## ■ Sample output file:

History number	Particle number	Projectile type	Interaction type	Target nucleus	Cell number	Energy deposited (MeV)	Time (shakes)	Collision position (x, y, z)			WGT	Generation number	Number of scatterings	Code
16	97	1	-99	1001	2	0.5309	8.095	43.57	4.88	1.84	1	3	5	0
16	97	1	-99	1001	2	0.0553	8.395	44.29	5.57	1.85	1	3	6	0
16	97	1	-99	1001	2	0.0014	11.722	44.92	5.04	3.78	1	3	9	0
109	1	1	0	6000	5	8.398	1.798	43.98	-7.52	6.31	1	0	0	0
132	1	1	-99	1001	5	13.9313	1.778	42.06	-2.98	1.42	1	0	2	0
132	1	1	-99	1001	5	0.1036	2.075	42.55	-2.34	2.88	1	0	3	0
132	1	1	-99	1001	5	0.0281	2.264	42.25	-2.39	3.44	1	0	4	0
132	1	1	-99	1001	5	0.0131	2.372	42.16	-2.22	3.63	1	0	5	0
335	58	1	-99	6000	4	0.0019	3.72	43.98	0.16	9.54	1	3	5	0
335	58	1	-99	1001	3	0.0042	4.069	42.64	-0.01	9.13	1	3	6	0
485	1	1	-99	1001	5	8.2582	1.872	48.08	-2.19	7.51	1	0	1	0
495	24	2	1	6	2	0.1461	1.036	43.87	3.46	5.06	1	1	2	0
495	24	2	1	6	2	1.2823	1.036	43.95	3.47	5.08	1	1	3	-1
495	24	2	1	6	2	0.038	1.038	43.41	3.8	5.12	1	1	4	-1
495	24	2	1	1	2	0.0793	1.038	43.28	3.76	5.08	1	1	5	-1
495	24	2	1	6	2	0.0421	1.042	43.69	3.19	5.93	1	1	6	-1

- From S.A. Pozzi et al. / *Nuclear Instruments and Methods in Physics Research A* 513 (2003) 550–558

# MCNP-DSP Overview

## ■ Modifications:

- Analog particle tracking
- Output given in data blocks of detector responses
- Correlates neutrons and gammas in time throughout fission chain mult. process
- Possible calculation modes: Source-driven noise analysis, Rossi-alpha, Pulsed source, Passive noise analysis, Multiplicity, Feynman variance
- Uses probability function  $P(\nu)$  rather than average  $\nu$
- Angular distribution of prompt neutrons from fission
- Fission neutron energy distribution
- Prompt gamma ray mult. for SF isotopes and Cf-252; energy distribution for Cf-252
- Can simulate capture, scatter, and fission neutron and gamma detectors
- Can simulate detector dead time

## ■ Limitations:

- Based on outdated version of MCNP - Format is not supported in Windows XP, Vista, 7
- Limited to ENDF/B-VI and older
- Limited to five detector channels

# PARTISN Overview

## ■ Modifications:

- Deterministic method – numerically solves multigroup form of Boltzmann transport equation using discrete ordinates (Sn) method
- Modular structure separates input processing, transport equation solving, and post-processing
- 1-D, 2-D, or 3-D geometries
- “diamond-differencing”, adaptive weighted diamond differencing, and linear discontinuous or exponential discontinuous special differencing schemes
- Time-dependent calculations
- Deterministic Feynman-Y point model capability added recently (asymptotic and coincidence gate-width dependence)

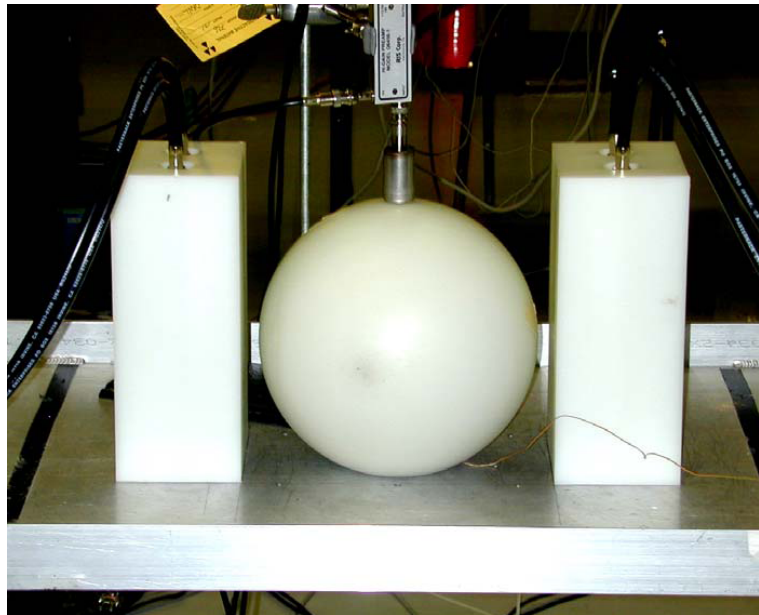
## ■ Limitations:

- Multiplicative analysis capability being investigated
- Not as accurate as MC
  - Due to multi-group cross-sections, geometric representation



## Task 3: Partially Completed

- Codes were compared using the BeRP Ball arrangement specified in the ICSBEP report SUB-PU-MET-FAST-001 in 3 configurations:
  - Bare
  - Surrounded by 3 inches of HDPE
  - Surrounded by 6 inches of HDPE (not done in benchmark)



## Task 3: Partially Completed

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- **Kcode calculations have been completed with MCNP5 and MCNPX for the bare, 3-inch, and 6-inch arrangements**
  - Results compared to benchmark to determine model validity
  - Calculations using both ENDF/B-VI and VII have been performed
- **List mode data have been generated with MCNP-PoliMi for the bare and 3-inch arrangements**
  - Feynman histograms will be created with post-processing code provided by LANL
- **No results from MCNP-DSP or PARTISN at this time**

## Task 3: Partially Completed

### ■ Kcode calculation results:

	Benchmark (MCNP/ENDF/B-VI)	MCNP5 1.51/ ENDF/B-VI	% difference	MCNPX 2.6.0/ ENDF/B-VI	% difference
Bare	0.77784±0.00004	0.77596±0.00006	0.24169	0.77563±0.00005	0.28412
3-in Poly	0.93721±0.00007	0.93693±0.00008	0.02988	0.93687±0.00009	0.03628
6-in Poly	N/A	N/A	--	N/A	--

	Benchmark (MCNP/ENDF/B-VI)	MCNP5 1.51/ ENDF/B-VII	% difference	MCNPX 2.6.0/ ENDF/B-VII	% difference
Bare	0.77784±0.00004	0.77762±0.00006	0.02828	0.77742±0.00005	0.05400
3-in Poly	0.93721±0.00007	0.93835±0.00008	-0.12164	0.93835±0.00009	-0.12164
6-in Poly	N/A	N/A	--	N/A	--

### ■ Other calculations to perform:

- Neutron leakage tallies
- Detector efficiencies

## Task 3: Partially Completed

### ■ MCNP-PoliMi output excerpt for 3-inch arrangement:

particle number	projectile type	interaction type	target nucleus	cell number of collision event	energy deposited in collision (MeV)	time (shakes)	collision position (x, y, z)			WGT	generation number	number of scatterings	code
18	1	-99	2003	58	0.20624	1.019	-26.28	-2.29	1.84	1	0	1	0
12	1	0	2003	58	2.42073	1.026	-24.51	-2.54	6.18	1	0	1	0
15	1	-99	2003	58	1.42718	1.053	-25.15	-3.17	2.34	1	0	1	0
11	1	-99	2003	40	0.78974	1.169	25.25	2.97	5.92	1	0	1	0
9	1	-99	2003	46	0.17272	1.347	25.11	-2.11	-0.4	1	0	2	0
6	1	-99	2003	58	0.24532	1.386	-25.13	-3.12	3.31	1	0	2	0
10	1	-99	2003	58	0.54088	1.739	-25.97	-3.35	3.84	1	0	3	0
11	1	0	2003	40	0.88908	2.357	25.15	2.62	6.67	1	0	2	0
6	1	0	2003	46	0.76822	2.448	24.46	-2.39	3.08	1	0	3	0
14	1	0	2003	40	1.123	3.166	25.54	2.49	3.19	1	0	1	0
7	1	-99	2003	58	0.13075	3.696	-25.86	-2.69	0.28	1	0	7	0
10	1	0	2003	52	0.79333	3.746	-24.31	2.13	6.52	1	0	8	0
15	1	0	2003	40	0.7702	4.228	24.91	2.77	3.62	1	0	6	0
17	1	0	2003	40	0.78207	4.959	24.72	2.05	2.06	1	0	7	0
6	1	0	2003	46	0.76858	5.221	24.34	-2.01	2.86	1	0	9	0
10	1	0	2003	52	0.77665	5.556	-26.21	3.1	6.46	1	0	6	0
14	1	0	2003	46	0.76699	6.56	25.55	-3.18	3.98	1	0	5	0
8	1	0	2003	58	0.76449	7.414	-25.5	-2.66	3.43	1	0	6	0
11	1	0	2003	40	0.76568	8.127	25.48	1.92	2.72	1	0	11	0

## Task 4: Not Completed

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- **Report will be submitted upon completion of Tasks 1 through 3**
  - Will contain the results of the simulations performed in Task 3 compared to the results from the simulations with the MCNP patch currently under development
  - Summaries of code capabilities will be included

# Summary

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- **Quarterly reports have been submitted to LANL highlighting progress towards completion of tasks**
  - Kcode simulations have been completed
  - List mode data
- **Final report will be submitted upon completion comparing simulation results from the various codes with those from the patch**